Binaural sensitivity in children with bilateral cochlear implants and in normal hearing children

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Introduction

- Spatial hearing tasks depend on access to binaural cues, such as interaural time and level differences (ITDs and ILDs).
- Binaural hearing provides reliable access to these cues in normal-hearing (NH) listeners.
- Patients who are fitted with bilateral cochlear implants (BiCIs) have little or no access to ITDs through their clinical processors. This led us to question whether children who use BiCIs are sensitive to ITDs.
- In addition, we compared ITD sensitivity in children with BiCIs with children with NH. The latter were tested with stimuli that mimic aspects of CI processing, namely transposed tones with high-rate carriers and low-rate envelope modulation (Ehlers et al., 2016).

Testing of BiCI users was conducted using bilaterally synchronized research processors (NIC2, L34s) with low-rate [100 pulses per second (pps)] stimulation on pitch-matched electrode pairs. ***Pitch-matched electrode pairs*** *were used because they typically yielded the best ITD sensitivity (Kan et al, 2013).*

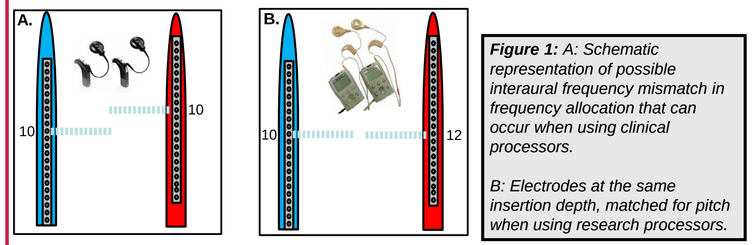


Figure 1: *A: Schematic representation of possible interaural frequency mismatch in frequency allocation that can occur when using clinical processors.*

B: Electrodes at the same insertion depth, matched for pitch when using research processors.

16 children with bilateral Cochlear Nucleus© devices

Subject	Chosen Electrode Pairs
CIAQ	4/4, 12/13, 20/19
CIAY	12/12, 20/18
CIDX	12/12
CIAP	4/4, 12/12, 20/16
CIBO	4/4, 12/12, 20/18
CIEB	12/12
CIAG	12/10, 4/4, 12/12, 20/18
CIEU	14/14, 4/4, 12/12, 18/18
CIBK	4/4, 12/12, 20/18
CIDQ	4/4, 12/12, 20/20
CIEH	4/6, 12/14, 20/20
CIDJ	6/6, 12/12, 20/16
CIEV	14/14
CIFF	14/14
CIEC	12/14
CIAW	14/16

- 300 ms, constant amplitude pulse train
- 25 µs pulse width
  - Experiment I: 100 pps
  - Experiment II:
    - 100 pps
    - 1000 pps
    - 1000 pps with 100 Hz AM
- Stimuli were presented via a pair of bilaterally synchronized L34 Speech processors (Cochlear Ltd.) at a self-reported comfortable level.

Mapping Procedure

- Threshold (T), comfortable (C), and maximum comfortable (MC) levels were measured through the L34 Speech processors for each stimulus separately.
- C levels were loudness-balanced between ears and also for the different maps.

NH children ITD and ILD sensitivity (Ehlers et al., 2016)

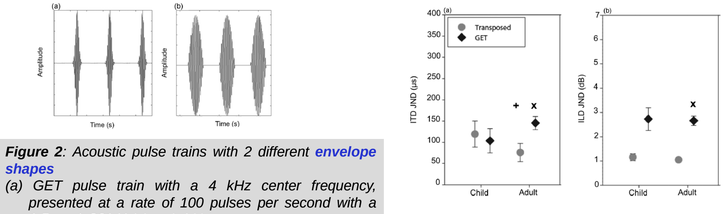
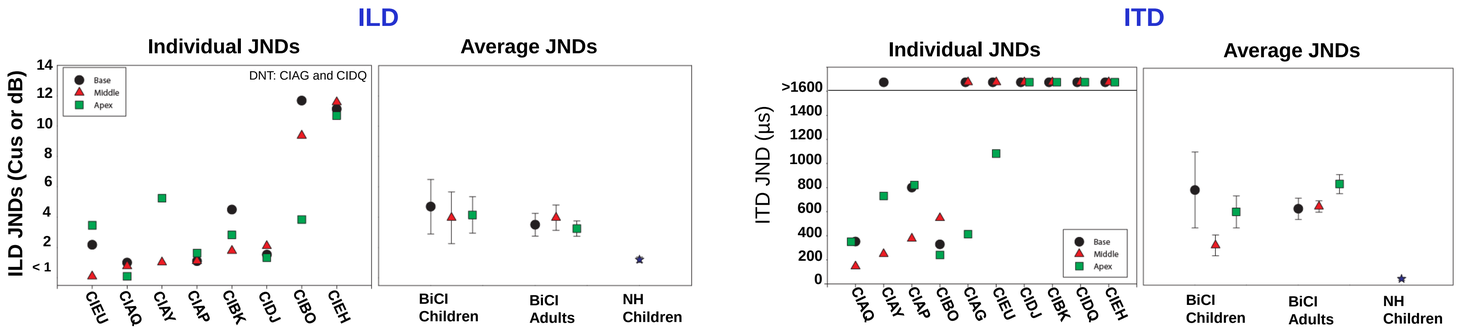


Figure 2*: Acoustic pulse trains with 2 different* ***envelope shapes***
(a) GET pulse train with a 4 kHz center frequency, presented at a rate of 100 pulses per second with a 1.5mm (~861 Hz) bandwidth .
(b) Transposed tone with a 4 kHz carrier tone modulated at a rate of 125 Hz.

Right-Left vs. Left-Right Discrimination

Figure 3: *Just noticeable difference (JND) thresholds are shown for individual (left) and group averages (right) for two sets of data: ILD and ITD.*
Color coding refers to three places of stimulation along the cochlear arrays (base, middle and apex) where pitch-matched electrode pairs were stimulated.



Lateralization (reporting intracranial position with a pointer)

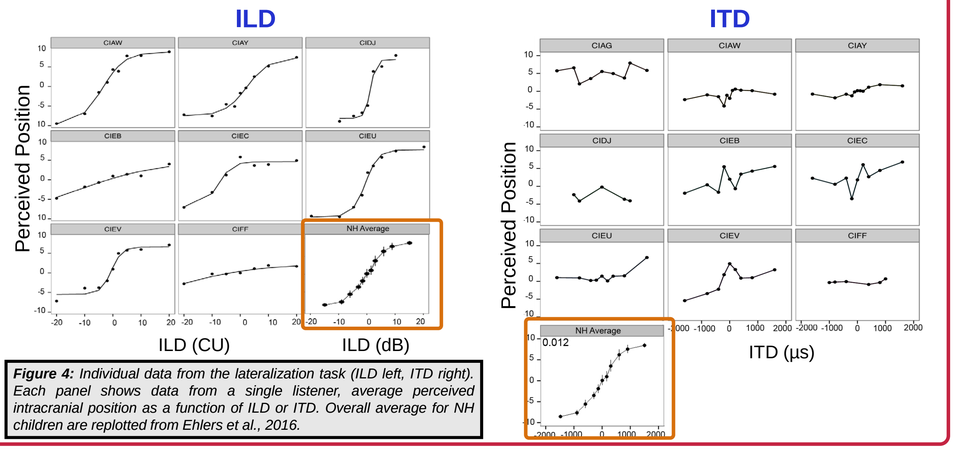


Figure 4: *Individual data from the lateralization task (ILD left, ITD right). Each panel shows data from a single listener, average perceived intracranial position as a function of ILD or ITD. Overall average for NH children are replotted from Ehlers et al., 2016.*

Direct Pitch Comparison and ITD JNDs

$\mu = (2)N_{much\ higher} + (1)N_{higher} + (0)N_{same} + (-1)N_{lower} + (-2)N_{much\ lower}$
where
N is the number of times a particular response was chosen

Subjects compared pitch in the two ears; and reported if the second sound was
"much higher" µ = 2
"higher" µ = 1
"same" µ = 0
"lower" µ = -1
"much lower" µ= -2
(Litovsky et al., 2012).

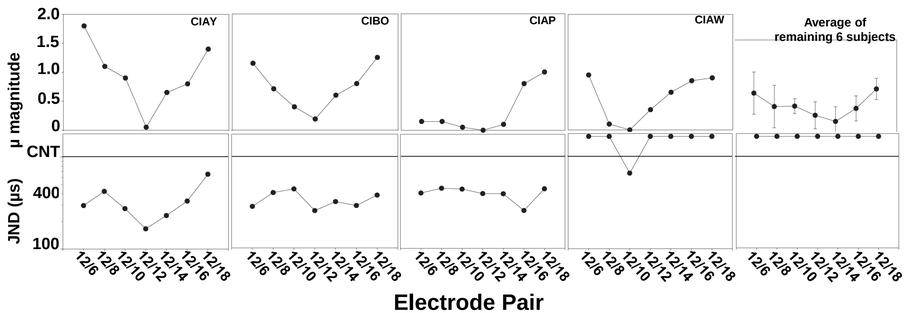


Figure 5: *ITD JNDs (bottom) for 4 children who had measurable JNDs are shown, along with those children's direct pitch comparison, µ magnitude (top). For the remaining children whose JNDs were not measurable the average µ magnitude values are shown (top, right)*

Pulsatile Stimulating Rate and ITD sensitivity

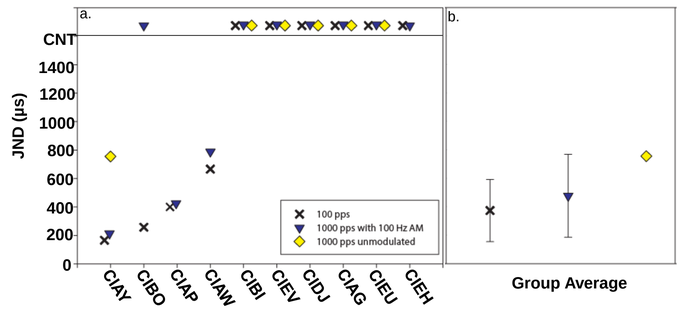


Figure 6: *Individual ITD JNDs for each stimulus condition (a) and average measurable JNDs for each stimulus condition (b).*

Conclusions

- A set of experiments on binaural sensitivity in children with bilateral cochlear implants (BiCIs) suggests that ILD sensitivity and intracranial lateralization are observed in all children.
- ITD sensitivity is restricted to a small number of children who previously had hearing experience; and lateralization is weak or absent in children with BiCIs.
- When ITD sensitivity occurs, it is at both 100 pps and 1000 pps with 100Hz AM.
- Pairing of electrodes across the two ears using the "direct pitch comparison" method sharpens the pitch matched pairing. ITD sensitivity may be slightly better for some subjects when DPC is used. The benefit of pitch matching for children with BiCIs for ITD sensitivity is not well understood, and may not be an efficient or helpful approach.

References

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